Momentum - an Idiot's guide*

Momentum is an attribute of moving objects, related to their velocity and their mass. It is what makes a heavy, moving object, like a snow boarding elephant, harder to stop than a light one, such as a vole on a tiny toboggan made from match sticks.

Momentum is a *vector* quantity, because it has both size and direction. Direction is obviously important - less momentum is transferred by a glancing blow than a full impact. The momentum of a moving body can be worked out by multiplying the mass by the velocity.

momentum = mass x velocity

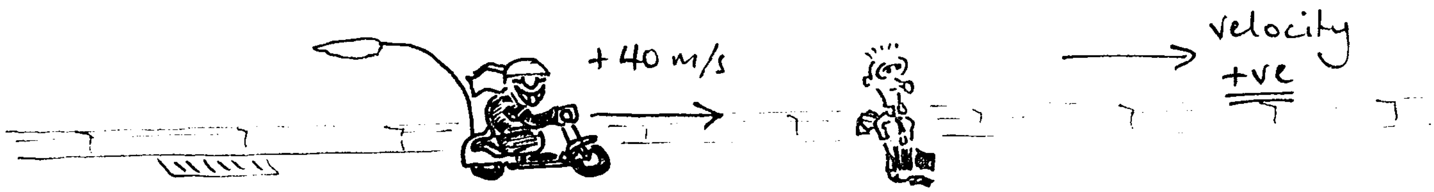
hence if SI units are used, momentum is measured in kgm/s.

As far as GCSE goes, momentum questions will be limited to one dimension of travel, which makes the whole thing a lot easier to deal with. There are two areas that questions are likely to be asked on: collisions/explosions and impulse.

Collisions and explosions - Your first driving lesson.

The vital factor in these questions is the *Law of Conservation of Momentum*. This sounds rather more impressive than it is. What it means is that the total momentum of all the objects involved is the same before and after the collision or explosion. As long as you remember to define velocity in one direction as positive, so that the velocity of objects moving in the opposite direction is negative, it's just a number crunching exercise.

e.g. A morally declining nun of 65 kg is hammering along the high street at 40 m/s on a stolen moped (135 kg) when she collides head on with a stationary stationery salesman of 85 kg, who becomes attached to the front of the moped as a result of being covered in envelope glue** . What is the moped's final speed?



Remember to define one direction as positive...
The total momentum will remain constant, so we can say:

momentum of nun & moped	+	momentum of salesman	=	momentum of both after collision

I use subscripts to remind me what I'm doing...

$m_n v_n \quad + \quad m_s v_s \quad = \quad mv$ now substitute in the numbers.

$(65 + 135)\text{x}40 \;+\; 85\text{x}0 \quad = \quad (65 + 135 + 85)\text{x } v$

The salesman's momentum is zero, as he isn't moving, so:

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* i.e. *Written* by an idiot, not used by one.
** Fortunately, no one was hurt...

$$200 \times 40 = 285 \times v$$

dividing each side of the equation by 285...

$$v = \frac{200 \times 40}{285}$$

$$v = 28.1 \text{ m/s (1d.p.)}$$

This is a simple example. If we replaced the salesman with a 20 kg ball of overcooked fettucine flying towards the nun at 30 m/s, then our initial equation would be:

$$200 \times 40 + (20 \times -30) = 220 \times v$$

because the pasta would have a negative velocity relative to that of our heroine. In an elastic collision, the problem is set up in exactly the same way, but information about the momentum of one of the bodies after the collision would be given.

Questions on explosions usually rely on stationary objects being flung apart or rockets changing speed. A rocket is propelled by a momentum exchange. Regardless of the actual velocity of the rocket, consider velocity *relative to it.* This means that the rocket's initial velocity is zero, by definition. To change speed, the rocket throws hot exhaust gases out of the back, so:

momentum of rocket = new momentum of rocket + momentum of exhaust gases

but if the rocket's initial relative velocity is zero, then:

new momentum of rocket = - momentum of exhaust gases

Given the masses, you can work out the new relative velocity of the rocket. This would be the change in velocity if the rocket is already in motion.

e.g. A pair of figure skaters are moving at a stately 2m/s. Deborah (55 kg), going backwards, suddenly finds that her Vick's spray has kicked in and becomes aware of her 75 kg partner's almost supernaturally powerful halitosis. She flings him away in the direction she is facing with a velocity of 4m/s, where he collides with a small child* (30 kg) and stops dead. Calculate the final velocities of both Deborah and the anonymous child.

Impulse.

Impulse can be explained as the force that a moving body can exert due to its momentum. In theory this is really only true for a collision taking place over a very short time, but for the purposes of the dull questions you'll be cranking out you can simply use the formula:

Impulse = Change in momentum.

$$F \times t = m_1v_1 - m_2v_2$$

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* Contrary to all expectation, the child is maimed. Guess this one will never get used in a GCSE.

Where F is the force exerted in newtons and t is the duration of the collision in seconds. Questions of this ilk usually involve some sort of projectile bouncing off an object, like an elk, or balls being struck with pieces of wood. Don't try this at home.

e.g. A solitary hunter lifts his head to salute the burgeoning glory of a perfect winter's morning. At this point he is shot by a vengeful elk with a high powered rifle and a steady hoof. Fortunately, the hunter has on bullet proof underwear, so nobody is hurt.
If the bullet has a mass of 50g and hits the hunter at 1000m/s, ricocheting off at 125m/s in the opposite direction, what is the total force exerted on the hunter if the impact takes place in 0.02 seconds?

e.g.2. A man swings his cat in the front room of his house whilst trying to prove a point to his landlord. The cat hits a lager can of mass 0.5 kg, exerting 120N on it for one hundredth of a second. Fortunately, no lager is spilled. What is the velocity of the can?

Footnote: Answers to the examples available at a modest sum. Practice is the key, but once you've got the hang of this, make up a question for a friend, it provides a great insight into exam questions. I almost always do a quick diagram. It gives you a nice, easy to read summary of the relevant facts and figures. Enjoy.

Extra questions.

1. Pinnochio is the subject of an assassination attempt! As the little 15 kg chap tries to run away at 12 m/s, he is hit between the shoulder blades with a 75 g bullet moving at 3000 m/s. Fortunately, as Pinnochio is made of wood, the only person hurt is the nurse who gets a splinter sanding around the edges of the wound prior to removing the bullet. At what velocity is he hurled forwards by the bullet?

2. Whilst in hospital, the brave little chap throws himself head on at a runaway nutcase doing 20 m/s in a wheelchair. He finds that by hitting the chair at 35 m/s, it ends up rolling backwards at 2 m/s with Pinnochio hanging on to the arm rests like grim death. What must the mass of the escapee and his wheelchair be?

3. A snooker cue exerts a 35 N force on a 600g cueball, which is accelerated from rest to 0.75 m/s. What was the duration of the shot? If the blue goes in, how many snookers does Steve Davis need to rebuild his tattered career? Who cares?